Hydrodynamic analysis of a continuous airlift bioreactor with flocculating high cell density system

J. Klein, A. A. Vicente, L. Domingues, [1]M. Juraščík, J. A. Teixeira
Centro de Engenharia Biológica, Department of Biological Engineering, University of Minho, Campus of Gualtar, 4710-057 Braga, Portugal; [1]Dept. of Chemical & Biochemical Engineering, Faculty of Chemical & Food Technology, Slovak University of Technology, Radlinského 9, 812 37 Bratislava, Slovakia, e-mail: jateixeira@deb.uminho.pt

One of the most common ways to improve the productivity of a fermentation process is the use of high cell density systems. In practice, such a system usually represents a three-phase (gas-liquid-solid) dispersion operating in a continuous mode. The interest for these biosystems has been increasing because they seem to be a very promising alternative to the traditional batch fermentation with freely suspended cells. The cells are usually immobilised on a carrier or in a simpler and cheaper way, they are self-aggregated forming flocs. High cell density biosystems have many specific advantages: higher volumetric productivity, higher product concentration and substrate conversion, easy separation of biocatalyst (cells) from the liquid medium, utilization of the same biocatalyst (cells) for extended periods of process time and a minimised risk of contamination.

A continuous airlift bioreactor (CALR) due to the advantageous combination of sufficient mixing, low shear stress and satisfactory flocs suspension at low power input is being often chosen for carrying out fermentations with high cell density. However, there is still a lack of reliable data on transport phenomena, which would allow bioreactor design and scale-up procedures to optimise a bioprocess performance at any bioreactor scale. In airlift bioreactors with a well-defined liquid circulation loop, the liquid velocity is the major hydrodynamic parameter, which considerably affects all physical phenomena. Most velocity measurement techniques are not suitable for use in fermentation processes (e.g. tagging of liquid elements with chemicals due to their interference with the exactly defined substrate pool and sterility problems, visual techniques as Laser Doppler Anemometry due to the opaqueness of the broth). The use of small flowfollowing particles with non-invasive detection of their movement is one of the promising methods. Detection techniques for opaque media include the use of radioactive counters, inductive coils and radio wave detectors.

One of the attractive possibilities for a utilization of high cell density system is alcoholic fermentation of lactose from cheese whey using flocculating yeast. Cheese whey, as a by-product of dairy industry, represents a significant environmental problem due to very high values of BOD and COD. For this purpose, a flocculating recombinant strain of *Sacharomyces cerevisae* was developed enabling the hydrolysis of lactose to galactose and glucose, followed by sugar conversion into ethanol.

The main goal of this study was to investigate the hydrodynamics of continuous airlift bioreactor during ethanolic fermentation using highly flocculating yeast. The magnetic particle-tracer method was used for hydrodynamic measurements. Different operation conditions (dilution and air flow rates and biomass concentration), bioreactor configuration and its scale (6 and 50 dm^3) have been applied in order to assess their impact on bioreactor hydrodynamics and its operation and to study scale-up effects on the bioprocess.

Measurements of liquid circulation velocity revealed one very important fact regarding to airlift bioreactor operation with high cell density system – the existence of a critical value of biomass concentration, at which a dramatic deceleration of net liquid flow

appears when the biomass quantity increases (see Figure). Moreover, the magnitude of critical biomass concentration was found not to be dependent on gas flow rate.

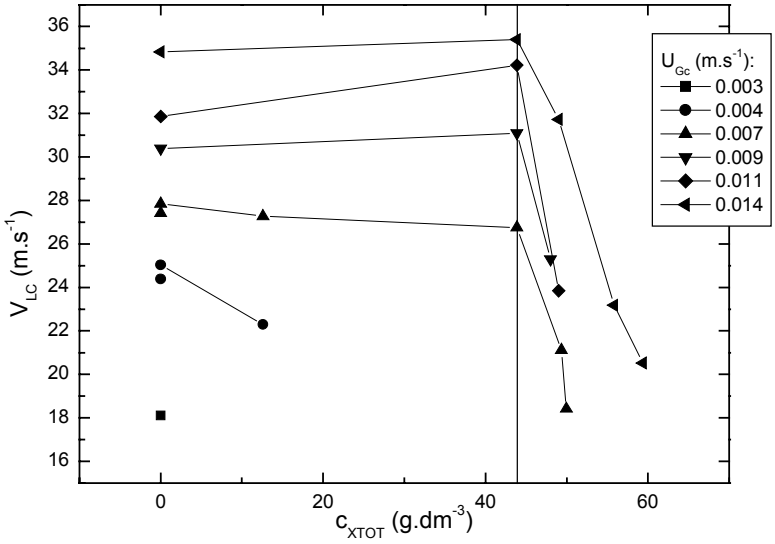

Figure. Effect of total biomass concentration in a 6 dm^3 ALR bioreactor, c_{XTOT}, on overall circulation velocity, V_{LC}, at different superficial gas velocity, U_{Gc}. A solid line marks a critical value of c_{XTOT}. A range of U_{Gc}. applied corresponds to the range of air flow rates Q_G from 0.1 to 0.45 vvm.

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